Power Matters

Microsemi

Microsemi Power Products

Arrow Vision Series – Power Management

2013

Microsemi Power Products

Power semiconductor solutions for high power and high frequency applications.

Switching Discretes

MOSFET: 200-1200V, 4 -175A
IGBT's : 600-1200V, 8-200A
Diode : 200-1200V, 5 – 100A

High Freq. VDMOS

2-300MHz
50 – 300V Operation
100 – 2,000 Watts
(parts not to scale)

Power Modules

Standard and Custom
Mosfet - IGBT - FRED - SiC
75V-1700V, 10A-750A
Low profile – high efficiency

Microsemi Power Products

Industry Leadership position in…

- **High Power Switching Devices**
  - ✓ Standard and Application Specific Power Modules
  - ✓ Power MOSFETs (Very fast switching, linear)
  - ✓ IGBTs (PT and NPT)
  - ✓ Fast Recovery Epitaxial Diodes (FREDs)
  - ✓ High Voltage Si Schottky diodes
- **Silicon Carbide Technology**
  - ✓ SiC Schottky Diodes
  - ✓ *SiC MOSFETs (in development)*
  - ✓ SiC Power Modules

- **RF Transistors and Hybrids**
  - ✓ High Voltage ISM-RF Vertical MOSFETS
  - ✓ RF ISM-RF MOSFET Driver ICs
  - ✓ RF ISM-RF Hybrids

Markets

★ Key Markets

- Industrial CO2
- Welding
- Induction Heating
- Vibration
- Plasma Cutting
- SMPS
- Down Hole
- e- Loads
- ★ Inverters
- Test Equip.
- Mfg Equip.
- Motor Control
- ★ Actuation
- Air Conditioning
- EV Charger
- E – Recovery
- EV Inverters
- MRI
- Treatment
- RF Scalpels
- CT Scanner
- X-Ray
- Semicap
- Flat Panel
- Solar Panel

Laser | Plasma | Medical | Transportation | Mil/Aero | Solar | Other Industrial

Power Matters

Microsemi

Microsemi SiC Product Overview

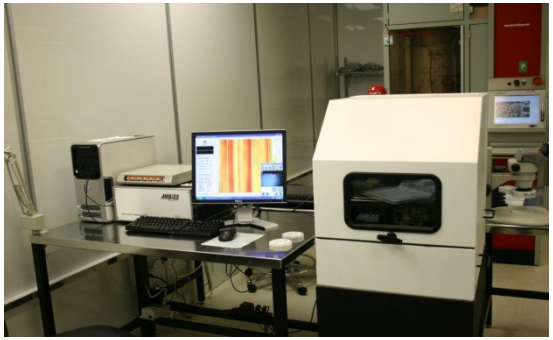
SiC Advantages

Characteristics	SiC vs. Si	Results	Benefits
Critical Electric Field	10x Higher	Lower On-Resistance	Higher efficiency
Band Gap	3x Higher	Higher operating temperature	Improved cooling
Thermal conductivity	2.5x Higher	Higher power density	Higher current capabilities
Positive Temperature coefficient	-	Self regulation	Easy paralleling
Temperature Independent switching behavior	-	Stable high temperature performance	Lower losses
Almost no Reverse Recovery charge	-	Lower switching losses Higher switching capabilities	Higher performance

Microsemi Investment in Silicon Carbide

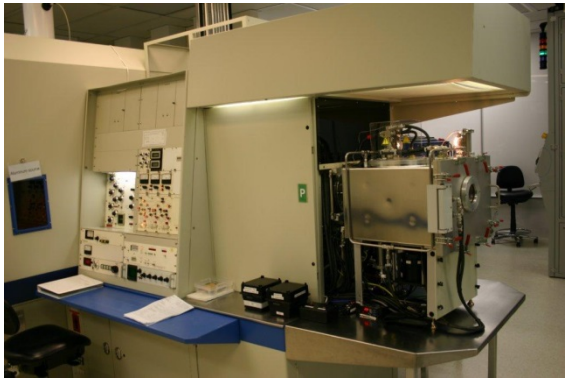
Microsemi SiC Design & Manufacturing in Bend Oregon

CentroTherm CHV-100
Post Implant Annealing to 1700C



Ambios AFM
Surface Roughness to 1Å

Hi Temp Oxidation
MESFET and MOSFET Gate Oxidation



CF3000
Implanter with Laboratory End Station for up to 1000C

E220
Production Implanter

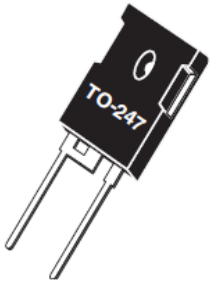
SiC Schottky Diodes

Patented SiC Schottky Barrier Diode Product

NEW!

1200V SiC Schottky Diodes

Volts	$I_{F(avg)}$ Amps	V_F (volts) Typ 25°C	Diode Series	Part Number	Package Style
SINGLE					
1200	10	1.5	SCD	APT10SCD120B	TO-247
	10	1.5	SCD	APT10SCD120K	TO-220
	20	1.5	SCD	APT20SCD120B	TO-247
	20	1.5	SCD	APT20SCD120S	D^3
	30	1.5	SCD	APT30SCD120B	TO-247
	30	1.5	SCD	APT30SCD120S	D^3
DUAL					
1200	10	1.5	SCD	APT10SCD120BCT	TO-247



TO-247[B]

D^3 PAK[S]

Coming Soon!

650V SiC Schottky Diodes

Volts	$I_{F(avg)}$ Amps	V_F (volts) Typ 25°C	Diode Series	Part Number	Package Style
SINGLE					
650	10	1.5	SCD	APT10SCD65K	TO-220
	20	1.5	SCD	APT20SCD65K	TO-220
	30	1.5	SCD	APT30SCD65B	TO-247
DUAL					
650	10	1.5	SCD	APT10SCD65KCT	TO-220

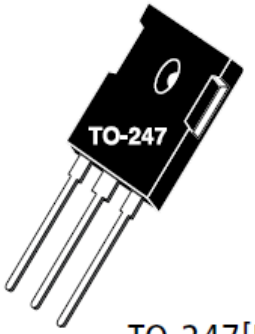

TO-220[K]

1700V SiC SBD coming late 2013

SiC MOSFETs

Patented Microsemi SiC MOSFET Product Roadmap

- SiC MOSFET **1200V**
  - 80 mΩ
  - 175C
  - Available mid-2014
- SiC MOSFET **1400V**
  - 175C
  - Available late 2014
- SiC MOSFET **1700V**
  - 175C
  - Available late 2014



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Microsemi SiC Advantages

Microsemi Advantages versus Competition

- **Superior passivation technology leads to higher reliability, thin film passivation in wafer fab for Microsemi vs. spin on passivation done post wafer fab for competitors**
- Patented technology: Junction barrier structure has a lower V_F than any equivalent die sizes (due to larger Schottky area and buried P-Wells)
- Tight V_F distribution due to high quality epi
- Optimized trade-off V_F and Qrr (small die size and smaller Qrr)
- Optimized trade-off V_F and BV (epi layer optimization)

Customer Case Study – SiC Diode for Solar

Application

Solar Inverter

Design Goal

Improve system reliability with new generation SiC Schottky Diode

Customer Options

- Microsemi's New 1200V 10A SiC Schottky Diode
- Competitor's Incumbent 1200V 10A SiC Schottky Diode

Customer Solution

Microsemi's New SiC Schottky Diode!

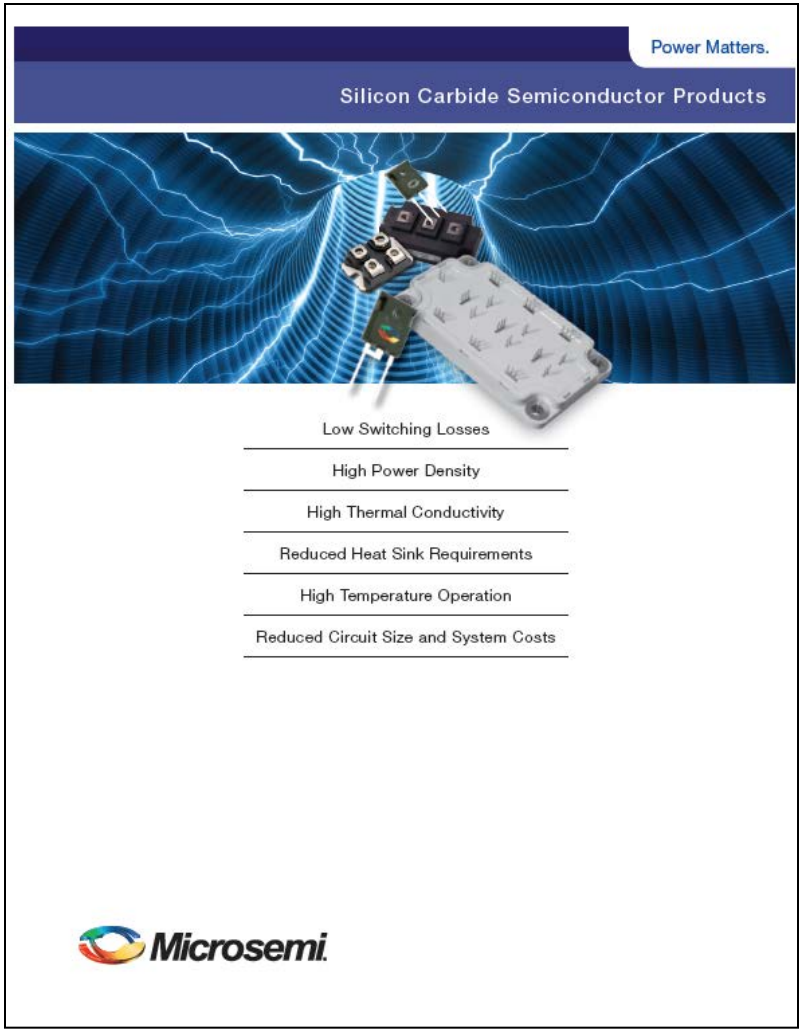
Microsemi Advantages

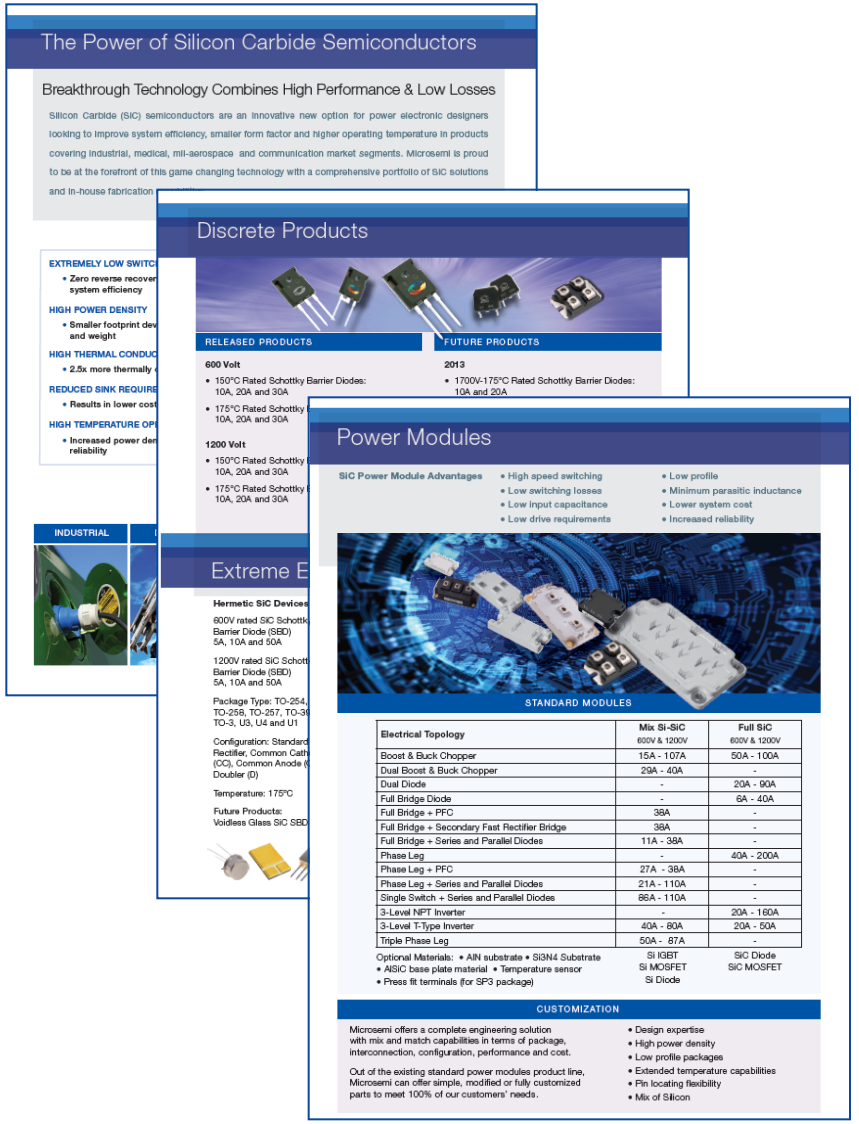
- Improved reliability in field trial. 1,250 systems in 6 month field trial with zero failures vs. previous supplier 2% per year failure rate
- Competitive price
- Strong customer support

SiC Applications

Markets		Applications	High Temperature	High Frequency	Small, Light System	Low Loss, Efficiency
Aerospace		Actuation Air Conditioning Power Distribution	X	X	X	X
Defense **Oil drilling**		Motor Drives Aux. Power Supplies	X	X	X	X
Transportation		Powertrain Fast Battery Charger DC/DC Converters KERS	X		X	X
Solar Energy		PV inverter		X	X	X
Wind turbine		Inverter		X	X	
Industrial		Motor drives Welding UPS, SMPS Induction Heating		X	X	X
Medical		MRI power supply X-Ray power supply		X	X	X

New SiC Product Brochure





Microsemi SiC Power Module Products

Power Modules with SiC built-in

- Complete product portfolio of semiconductor technology using the highest performance SiC semiconductors available on the market.

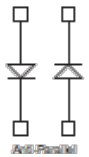
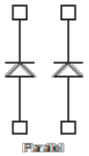
- Optional material assemblies using DBC on AlN or Al2O3, Copper or AlSiC base plate as well as custom product capabilities to address industrial and extended temperature range applications.

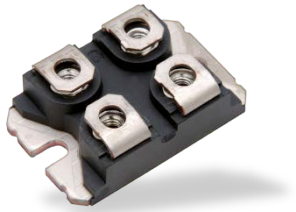
- SiC power modules advantages:
  - High speed switching
  - Low switching losses
  - Low input capacitance
  - Low drive requirements
  - Low profile and minimum parasitic inductance
  - Lower system cost

- Modules designed for high frequency, high performance, high density and energy saving power systems such as solar inverters, uninterruptible and switched mode power supplies, and welding machines.

SiC Diode Power Modules

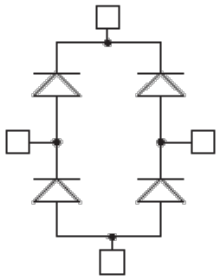
DUAL DIODE

V_{RRM} (V)	DIODE Type	IF (A) T_C=100° C	VF (V) T_J=25° C	Package		
600	SiC	20	1.6	SOT-227	APT2X20DC60J	APT2X21DC60J
		30	1.6	SOT-227	APT2X30DC60J	APT2X31DC60J
		40	1.6	SOT-227	APT2X40DC60J	APT2X41DC60J
		50	1.6	SOT-227	APT2X50DC60J	APT2X51DC60J
		60	1.6	SOT-227	APT2X60DC60J	APT2X61DC60J
		90	1.6	SP1	-	APTDC902U601G
1200	SiC	20	1.6	SOT-227	APT2X20DC120J	APT2X21DC120J
		30	1.6	SOT-227	APT2X30DC120J	APT2X31DC120J
		40	1.6	SOT-227	APT2X40DC120J	APT2X41DC120J
		50	1.6	SOT-227	APT2X50DC120J	APT2X51DC120J
		60	1.6	SOT-227	APT2X60DC120J	APT2X61DC120J



SOT-227

FULL BRIDGE

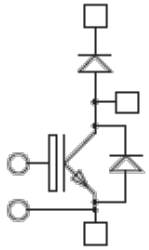


V_{RRM} (V)	DIODE Type	IF (A) T_C=100° C	VF (V) T_J=25° C	Package	Part Number
600	SiC	6	1.6	SOT-227	APT06DC60HJ
		10	1.6	SP1	APTDC10H601G
		20	1.6	SP1	APTDC20H601G
		40	1.6	SP1	APTDC40H601G
		40	1.6	SOT-227	APT40DC60HJ
1200	SiC	10	1.6	SOT-227	APT10DC120HJ
		20	1.6	SP1	APTDC20H1201G
		20	1.6	SOT-227	APT20DC120HJ
		40	1.6	SP1	APTDC40H1201G
		40	1.6	SOT-227	APT40DC120HJ

SP1

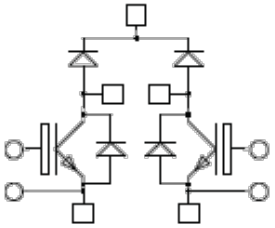
12mm height – Isolated packages
Solder pins (SP1) or screw terminals (SOT-227)

IGBT + SiC Diodes Power Modules



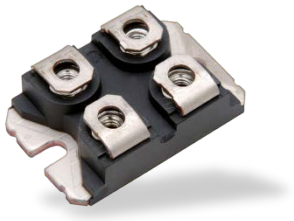
BOOST CHOPPER

V_{RRM} (V)	IGBT Type	IC (A) T_C=80° C	$V_{CE(on)}$ (V) at rated Ic	Package	NTC	Part Number	
600	NPT	50	2.1	SOT-227	-	APT50GF60JCU2	
		90	2.1	SP1	YES	APTGF90DA60CT1G	
1200	NPT	15	3.2	SOT-227	-	APT15GF120JCU2	
		25	3.2	SOT-227	-	APT25GF120JCU2	
		50	3.2	SP1	YES	APTGF50DA120CT1G	
	TRENCH 4 FAST	25	2.05	SOT-227	-	APT25GLQ120JCU2	*NEW!*
		40	2.05	SOT-227	-	APT40GLQ120JCU2	*NEW!*



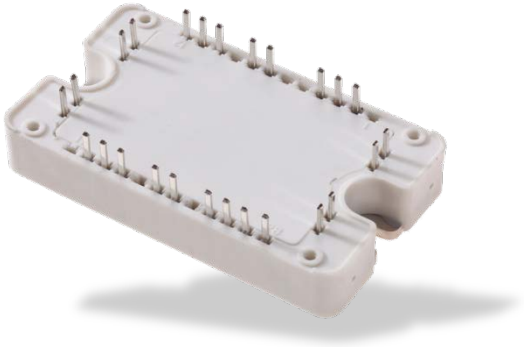
DUAL CHOPPER

V_{RRM} (V)	IGBT Type	IC (A) T_C=80° C	$V_{CE(on)}$ (V) at rated Ic	Package	NTC	Part Number	
1200	TRENCH 4 FAST	40	2.05	SP3F	YES	APTGLQ40DDA120CT3G	*NEW!*



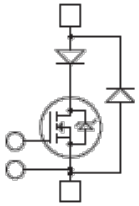
SOT-227

SP1



SP3F

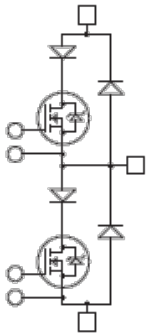
MOSFET + SiC Diodes Power Modules



SINGLE SWITCH + SERIES FRED AND SIC PARALLEL DIODES

V_{DSS} (V)	MOSFET Type	$R_{DS(ON)}$ (mΩ)	I_D (A) T_C=80° C	Package	NTC	Part Number
1000	MOS7	65	110	SP6	option	APTM100UM65SCAVG
1200	MOS7	100	86	SP6	option	APTM120U10SCAVG

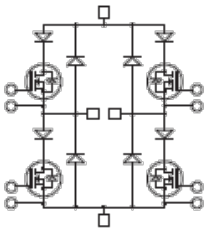
SP4 17mm



PHASE LEG + SERIES FRED AND SIC PARALLEL DIODES

V_{DSS} (V)	MOSFET Type	$R_{DS(ON)}$ (mΩ)	I_D (A) T_C=80° C	Package	NTC	Part Number
500	MOS 7	38	67	SP4	YES	APTM50AM38SCTG
		24	110	SP6	-	APTM50AM24SCG
600	COOLMOS	35	54	SP4	YES	APTC60AM35SCTG
		24	70	SP4	YES	APTC60AM24SCTG
		18	107	SP6	-	APTC60AM18SCG
900	COOLMOS	60	44	SP4	YES	APTC90AM60SCTG
800	COOLMOS	150	21	SP4	YES	APTC80A15SCTG
		100	32	SP4	YES	APTC80A10SCTG
		75	43	SP6	-	APTC80AM75SCG
1000	MOS 7	130	49	SP6	-	APTM100A13SCG

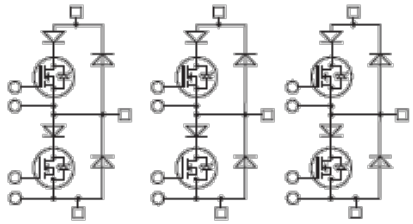
SP6 17mm



FULL BRIDGE + SERIES FRED AND SIC PARALLEL DIODES

V_{DSS} (V)	MOSFET Type	$R_{DS(ON)}$ (mΩ)	I_D (A) T_C=80° C	Package	NTC	Part Number
500	MOS 7	75	34	SP4	YES	APTM50HM75SCTG
600	COOLMOS	70	29	SP4	YES	APTC60HM70SCTG
		45	38	SP4	YES	APTC60HM45SCTG
800	COOLMOS	290	11	SP4	YES	APTC80H29SCTG
900	COOLMOS	120	23	SP4	YES	APTC90H12SCTG
1000	MOS 7	450	14	SP4	YES	APTM100H45SCTG

SP6P 12mm



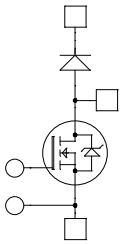
TRIPLE PHASE LEG

V_{DSS} (V)	MOSFET Type	$R_{DS(ON)}$ (mΩ)	I_D (A) T_C=80° C	Package	NTC	Part Number	
600	COOLMOS	24	87	SP6-P	YES	APTC60TAM21SCTPAG	*NEW!*
1000	MOS 7	350	50	SP6-P	YES	APTM100TA35SCTPG	*NEW!*

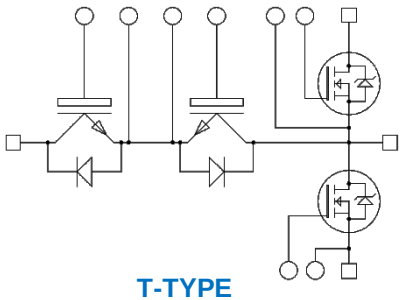
SiC MOSFET Power Modules

NEW PRODUCTS

PART NUMBER	TOPOLOGY	BVDS (V)	Id (A) @ Tc=80C (A)	RdsON (mR) @ Tj=25C	NTC	PACKAGE
APT50MC120JCU2	PFC	1200	50	40	-	SOT-227
APT100MC120JCU2	PFC	1200	100	20	-	SOT-227
APTMC120HR11CT3G	T-Type	1200	20	110	YES	SP3F
APTMC120HRM40CT3G	T-Type	1200	50	40	YES	SP3F
APTMC60TL11CT3AG	Three level inverter	600	20	110	-	SP3F
APTMC60TLM55CT3AG	Three level inverter	600	40	55	YES	SP3F
APTMC60TLM20CT3AG	Three level inverter	600	100	20	YES	SP3F
APTMC60TLM14CAG	Three level inverter	600	160	14	-	SP6
APTMC120AM55CT1AG	Phase Leg	1200	40	55	YES	SP1
APTMC120AM20CT1AG	Phase Leg	1200	100	20	YES	SP1
APTMC120AM08CD3AG	Phase Leg	1200	185	8	-	D3



PFC



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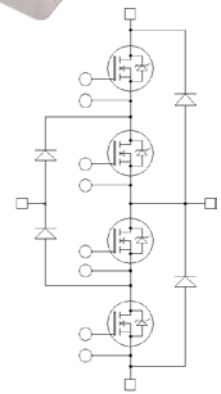
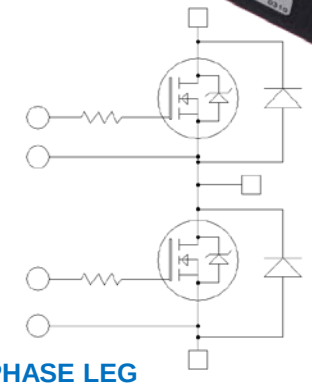


3-LEVEL



PHASE LEG

Key Market: Welding & Plasma Cutting

Frequency	30KHz to 100KHz
Voltage	500V to 1200V
Power	up to 30KW

Resonant mode or Phase shift

- MIG/MAG Welders
- Plasma Cutters
- TIG AC & DC Welders
- STUD Welding

Standard Microsemi Modules:

- **Input Bridge Rectifier**– Rectifier Diode Modules
- **PFC**– Chopper Modules, PFC
- **Inverter**– MOSFET (Si/SiC), IGBT
- **High Surge Current Fast Diode**– Full Bridge/Single FRED and Dual SiC Schottky Diodes

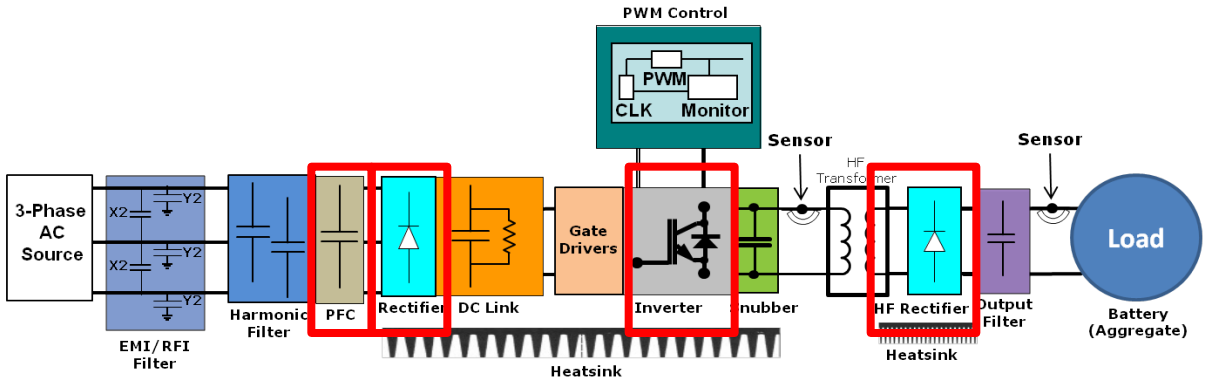
Size, Performance and Reliability…

Key Market: Battery Charger for Electric Vehicles

OFF-BOARD BATTERY CHARGER:

Target Market: DC Fast Chargers (Level 3)

Level III EV Battery Charger Block Diagram



Power Factor Correction

APTGF75DA120T1G
APTGF100DA120T1G

AC-DC Rectifier

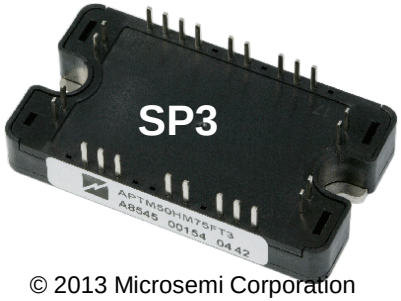
APTDR40X1601G
APTDR90X1601G

DC-AC Inverter

APTGF75H120T3AG
APTGL90H120T3G

High Frequency Rectifier

APTDF60H1201G
APTDF100H1201G



Power Matters

Microsemi

Microsemi NPT IGBTs

1200V NPT IGBTs

Discretes and Modules

The New NPT IGBT Benchmark

Microsemi Power MOS 8™

Fast

Switching speeds up to 100 kHz!

Efficient

13% - 60% lower switching losses than competitors' IGBTs

Low Cost Solution

Microsemi's new NPT IGBTs can replace 1000V to 1200V MOSFETs in applications up to 100 KHz at lower costs

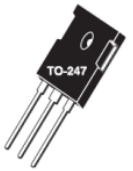
Product Family

- 25A to 85A discrete IGBTs
- Up to 600A modules
- Microsemi New Mos8 Proprietary Technology

1200V NPT IGBTs

BVces Volts	Vce(on) Typ 25°C	Ic2 100°C	Maximum Ic at Frequency		Part Number	Package Style
SINGLE			50 kHz	80 kHz		
1200	2.5	25	25	21	APT25GR120B	TO-247
	2.5	25	25	21	APT25GR120S	D^3
	2.5	40	38	28	APT40GR120B	TO-247
	2.5	40	38	28	APT40GR120S	D^3
	2.5	50	48	36	APT50GR120B2	T-MAX®
	2.5	50	48	36	APT50GR120L	TO-264
			25 kHz	50 kHz		
	2.5	70	66	42	APT70GR120B2	T-MAX®
	2.5	70	66	42	APT70GR120L	TO-264
	2.5	70	42	30	APT70GR120J	ISOTOP®
	2.5	85	72	46	APT85GR120B2	T-MAX®
	2.5	85	72	46	APT85GR120L	TO-264
	2.5	85*	46	31	APT85GR120J	ISOTOP®
Combi (IGBT & Diode)			50 kHz	80 kHz		
1200	2.5	25	25	21	APT25GR120BD15	TO-247
	2.5	25	25	21	APT25GR120SD15	D^3
	2.5	25	25	21	APT25GR120BSCD10	TO-247 (w/ SiC Diode)
	2.5	25	25	21	APT25GR120SSCD10	D^3 (w/ SiC Diode)
	2.5	40	38	28	APT40GR120B2D30	T-MAX®
	2.5	40	38	28	APT40GR120B2SCD10	T-MAX® (w/ SiC Diode)
			25 kHz	50 kHz		
	2.5	50*	42	32	APT50GR120JD30	ISOTOP®
	2.5	70*	42	30	APT70GR120JD60	ISOTOP®
	2.5	85*	46	31	APT85GR120JD60	ISOTOP®

** Ic2 for ISOTOP® packages measured at 70 °C for 1200V NPT IGBTs*

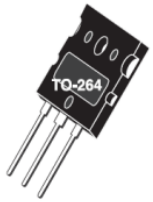


TO-247[B]

D³ PAK[S]

T-MAX®[B2]

T-MAX®[B2]



TO-264[L]

ISOTOP®[J]
SOT-227

New 650V NPT IGBTs: 45A, 70A & 95A

Features

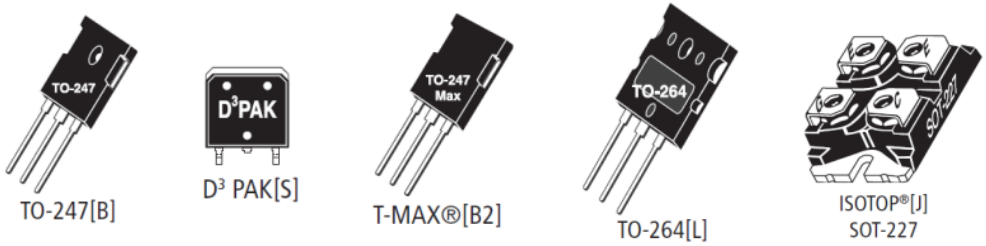
- Rugged MOS 8™ technology
- Vce(on): 1.9V
- Positive temperature coefficient

IGBT Products	Product Release
APT45GR65B	**Available Now**
APT70GR65B	**Available Now**
APT95GR65B2	**Available Now**
APT45GR65BSCD10	October 2013
APT45GR65BDU30	November 2013
APT70GR65B2DU40	November 2013
APT95GR65JDU60	December 2013

Benefits

Total switching loss 8% lower than top competitors

- Low Eoff (70A, 25C, 5Ω, Vbus: 400V)= 1.06mJ
- Best trade-off between conduction and switching losses
- Low turn-off EMI
- SCWT rating: 10 µs
- Tight parameter distribution



TO-247[B] D³ PAK[S] T-MAX®[B2] TO-264[L] ISOTOP®[J] SOT-227

Customer Case Study – IGBTs

Application

Medical: MRI Gradient Amplifier (20kHz Inverter)

Design Goal

Improve system efficiency with new generation IGBT

Customer Options

- Microsemi 1200V NPT IGBT 85A
- Competitor's Fast IGBT

Customer Solution

Microsemi's New 1200V NPT IGBT!

Microsemi Advantages

- 6% lower total power loss
- Low E_{off} and E_{on2} for fast switching
- Optimized trade-off of $V_{ce(on)}$ and E_{off}
- Optimized trade-off of Q_{rr} and V_F

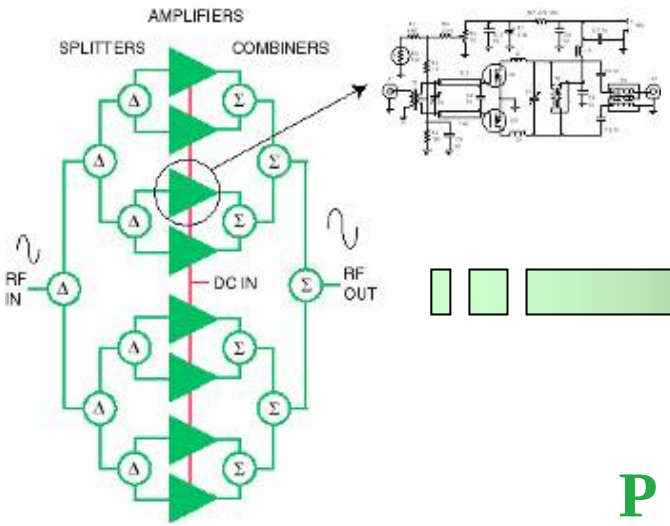
Power Matters

Microsemi

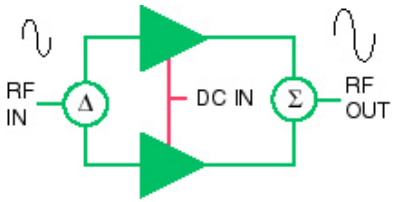
High Voltage RF MOSFETs

The High Voltage Advantage

Typical High Power, 50V RF Amplifier



The ARF High Voltage Solution



$$P = \frac{V^2}{R}$$

300 W Amplifier x 8 = 2 kW out

- **Big Amplifiers are complex**
- **They require a lot of "Glue"**
  - **Splitters**
  - **Combiners**
  - **Pieces parts**
- **System complexity drives cost**

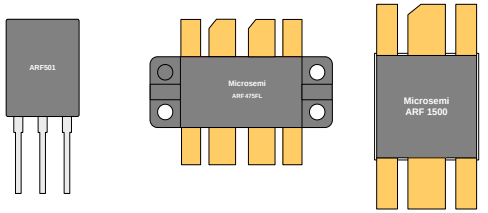
1 kW Amplifier X 2 = 2 kW out

- **One Splitter and Combiner**
- **10% Higher Efficiency**
- **350 W less DC input power**
- **80% Fewer Parts**
- **Lower Cost & Smaller Size**

ISM Product Categories

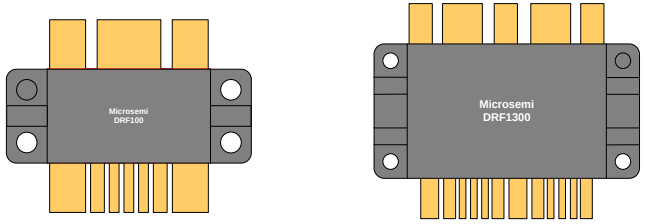
ARF

- High Voltage RF MOSFETs
- 500V to 1000V Breakdown, 100 to 400V applications
- 100W to 1000W in Power Output
- 2MHz to 150MHz Operating Frequencies
- N and P channel transistors
- Class-A, B, AB, C, D, E



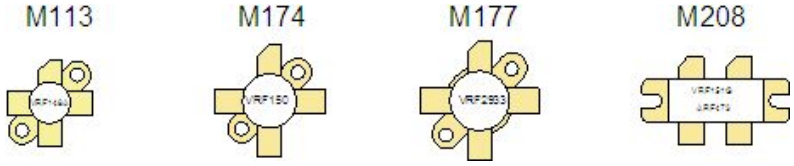
DRF

- High Voltage RF Hybrids and Driver IC
- 500V to 1000V Breakdown, 110V to 1000V applications
- 1000W to 3000W in Power Output
- 2MHz to 40MHz Operating Frequencies
- Class-D and E Switch mode applications over 30 MHz

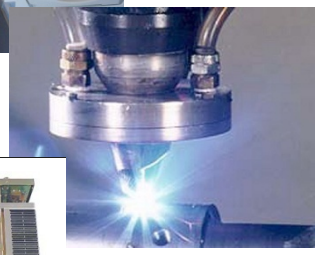


VRF

- Low Voltage RF MOSFETs
- 50V to 270V Breakdown, Rugged
- 50V applications - VRF family of 170V RF MOSFETs
- 90V applications – VRF19x 270V RF MOSFET
- 30W to 600W in Power Output
- 2MHz to 150 MHz Operating Frequencies
- Class A, AB, B, C, E



ISM Markets



Industrial plasma	- Semi-Cap - Industrial Glass - PV Cells - Flat Panel Displays - Induction Heating - Hazardous gas treatment - Lighting - Ignition	ARF VRF DRF
Medical	- MRI - Laser Scalpel - Diathermy - Chemical Analysis	ARF VRF
Laser	- Machine Tools - Drilling - Marking - Cutting - Welding	ARF VRF DRF
Communications	- Marine Radio - HF Radio - FM Broadcast	ARF VRF

Thank You.

Microsemi

For More Information:
Existing Arrow Customers: 800 777 2776
New Customers: 800 833 3557
www.arrownac.com/powermanagement